Discussion Paper No. 15

FARMING SYSTEMS RESEARCH AT ICARDA

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I. INTRODUCTION

The International Center for Agricultural Research in the Dry Areas (ICARDA) is located in Syria. Its headquarters are in Tel Hadya, a 948 ha farm, 30 km south of Aleppo. ICARDA was founded in 1977 and had its administrative headquarters in Beirut until all offices were moved to Tel Hadya in 1981. Aleppo province was chosen as the center of research activities because it is possible to observe different environmental conditions within the limits of an area covered by a 100 km radius. For example, rainfall (long term averages) reduces from 477 mm in the northwest at Jindiress near the Turkish border to 219 mm at Khanasser, 100 km to the southeast. Tel Hadya, more or less in the middle, averages 389 mm. Similar variation can be observed in soils, social conditions, etc., but, for rainfed agricultural production in West Asia and North Africa (WANA), climatic variability is considered

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to be a crucial constraint. Hence, Aleppo province provides quite a suitable environment in which agricultural research for diverse rainfed conditions can be conducted.

Within the Consultative Group for International Agricultural Research (CGIAR), ICARDA currently has a regional mandate covering West Asia and North Africa. This region extends from Pakistan to Morocco and from Turkey to Ethiopia. Cropwise, it has the global mandate to coordinate research on barley, lentils and faba beans. On a regional basis it conducts research on chickpeas in collaboration with the International Center for Research in the Semi-Arid Tropics (ICRISAT) and in wheat (bread and durum) in collaboration with the International Wheat and Maize Improvement Center (CIMMYT). ICARDA also conducts research in pasture and forage improvement as well as livestock management.

The salient characteristic of ICARDA is the adoption of the farming systems perspective in agricultural research. These research activities at ICARDA are organized along four programs:

1. Farming Systems Program (FSP)
2. Cereals Improvement Program (CP)
3. Food Legume Improvement Program (FLIP)
4. Pasture, Forage and Livestock Program (PFLP)

In addition to these, there is a Genetic Resources Unit (GRU), a computer center, a training center, a communications unit and various laboratories and workshops.

FSP consists of a multidisciplinary team of scientists who work together and in cooperation with other programs of ICARDA. Currently the program contains scientists with expertise in agronomy, soil chemistry, soil physics, water management, weed control, agroclimatology, economics, sociology and anthropology. The combined expertise of these scientists, coupled with other disciplines such as those of plant breeding, entomology, pathology, physiology, microbiology, livestock husbandry and range management which are found in ICARDA's other programs, allows ICARDA to conduct its research in the context of the whole farming system. One basic tenet is that in the extremely difficult dry areas, one discipline, by itself, cannot provide the fulcrum which can bring about technological developments in agriculture. Hence, interdisciplinary research is integral to FSP and ICARDA activities.

The FSP perceives its research as a process that passes through four stages. These stages are: diagnostic, design or experimental, testing, and extension. While this terminology has been popularized by FSR practitioners, in essence, it is not different from any other applied research process. Such processes would follow the sequence of problem identification, evaluation of existing knowledge, experimentation and testing of hypotheses and finally, the development of alternative solutions for implementation.

FSR is problem-oriented; a proper diagnosis and a clear definition of the problem is of paramount importance if the effort is to succeed. This will determine the make-up of the team and the allocation of research effort to the various stages. Indeed, problem-oriented research acts to keep the team together, and the effort focused and on schedule. This process is dynamic and iterative since we frequently return to previous stages to clarify points as we gain knowledge, confront problems, and consider research alternatives. In addition, the distribution between stages is not sharply defined as there is much overlap, and we work at several stages simultaneously.

II. GOALS AND LONG RANGE OBJECTIVES

ICARDA's mandate is based upon the concept of FSR, and thus the program and the Center share a common ultimate goal of increasing both the level and stability of production, in a region characterized by great seasonal variation in climate, and by diverse social and economic conditions.

An agricultural system is determined by its natural and human resources, its historical development, and current social and economic environment. Due to the large and diverse nature of ICARDA's region, these combinations of factors result in numerous different systems, each unique in its own way. FSR does not aim, therefore, to develop an improved system of wide applicability.

Bearing this in mind the program has the following long-range objectives:

- To establish an FSR methodology which can be demonstrated successfully in our core research program in Syria. This objective has been largely met during the last four years. However, both the need to maintain some flexibility in the methodology and the time required to thoroughly demonstrate the success of the methodology, require that this should remain a major objective in the immediate future.

- To conduct research for development of improved farm practices as components of improved systems.

- To foster the initiation of FSR within ICARDA's region through cooperative projects with national programs and through training of regional personnel.

- To assess and demonstrate the regional applicability of the results of our technical core research program through the use of a comprehensive agro-ecological zonation process.

III. RESEARCH AND TRAINING STRATEGY WITHIN THE CORE PROGRAM

FSR can be used to solve a wide range of agricultural problems. In order to allocate our financial and personnel resources efficiently, we have chosen problem areas that:

- Complement the commodity programs' research,
- Have a reasonable chance of being successful in a relatively short time period,
- Will give us experience in all phases of FSR, and
- Will expose us to a broad range of agricultural activities characteristic of the ICARDA region.

Based on these criteria, the FSP is now organized into five research projects. Much of the research described in projects 1-3 is currently conducted in Syria, but many of the fundamental principles which we are expounding have a broad regional applicability. The feasibility of transfer of these basic principles for adaptation to specific situations is evaluated through our agroclimatic zoning work, our cooperative research projects, through our training program, our workshops, our publications and through regional travel by our scientists.

1. Barley/Livestock Farming Systems

The aim of the project is to enhance productivity, yield stability, and rural income of farmers practicing integrated barley/livestock farming systems in areas receiving less than 350 mm rainfall, through improved crop management, alternative crop rotations, improved integration of crop/livestock activities, and a more efficient use and maintenance of the natural resource base with special reference to improved water and soil nutrient use efficiency.

The research conducted within this project recognizes that the central feature of these systems in WANA is livestock, principally sheep. Thus, in identifying research priorities from diagnostic survey work, emphasis has been placed on understanding the annual feeding cycle of sheep. Currently, our research focuses on short term and long term objectives. Short term objectives look at ways in which readily adoptable improvements can be made in existing farming practices. Main areas of research include:

a) Improved barley production (largely through fertilizer use).
b) Increased efficiency of supplementary winter feeding.
c) Greater productivity of communal grazing areas.

Our longer term objective involves studying the agronomic and economic feasibility of introducing forage legumes, i.e., annually sown vetch or self regenerating medic pastures, into these systems which now are heavily dependent on cereal production. Such forages are being evaluated on station and on-farm for suitability and productivity both as sources of spring grazing and sources of stored winter feed following harvest of the mature crop. Much of this latter work is conducted in collaboration with scientists in ICARDA's Pasture, Forage and

Livestock Program (PFLP).

2. Wheat Based Farming Systems

The main objective of the project is to enhance productivity, yield stability, and rural income of farmers in areas receiving more than 350 mm of rainfall where wheat, food legumes, and summer crops are predominant. The principal emphasis is on improvements in wheat and food legume production whilst ensuring that improvements in these components are evaluated in the context of the whole farming system.

Wheat is a crop of major importance in our region, and much of our work focuses on this crop. Current research involves:

a) Long term rotation trials on tillage, fertilizer, and herbicide use.

b) Long term trials contrasting different two course wheat/legume and wheat/summer crop rotations.

c) Survey work and on-farm trials to investigate current wheat production strategies and demonstrate and evaluate improved crop husbandry techniques with special reference to phosphate, nitrogen and herbicide use.

d) Use of crop growth models to predict long term performance of contrasting wheat cultivars in variable environments to assist breeders in germplasm evaluation and distribution.

e) Development of improved nitrogen fertilizer use strategies by farmers based on probability analyses of long run climatic data sets.

Our work on food legumes is conducted in close cooperation with our Food Legume Improvement Program (FLIP) and has centered around survey work and on farm evaluation of three principal innovative production technologies.

i) Early sowing of lentils.

ii) Mechanization of lentil harvesting.

iii) Winter sowing of chickpeas.

In addition to the principal areas of research on wheat and food legumes we have conducted some research on fertilization of summer crops (watermelon), and will shortly be joined by a post graduate who will be evaluating the integration and importance of livestock in these farming systems.

3. Inter-Systems Research

The aim of the project is to provide quantitative information on the effect of variability in climate, soils, and socio-economic conditions on the farming systems of the region, and to provide a basis for the extrapolation of research results from a limited number of locations and seasons, to other similar locations or environments that may differ in known respects.

This project contains a variety of research topics of considerable importance and relevance to all farming systems of the region. Because of the great variability of soil and environmental factors which span across the rainfall isohyets, these topics are most suitably studied, analysed and reported within this context. Nevertheless, results obtained from this work naturally have relevance to specific farming systems. Important examples of research reported within this project are:

a) Phosphate reaction in rainfed calcareous soils.

b) Regional standardization of soil analyses.

c) Role and impact of supplementary irrigation in rainfed agriculture.

d) Development of multiple season/multiple site trials and related analytical techniques.

e) Climatic analyses and agroclimatic zonation.

f) Rainfall intensity/soil erosion studies.

g) Bacterial classification of soils.

h) Supply response analyses for principal ICARDA crops.

4. Cereal/Livestock Systems In Tunisia

This project is largely funded by a restricted core grant from IDRC, and the bulk of the work to be undertaken by Tunisian national scientists based in INRAT and INAT. However, ICARDA provides an international staff member from the core budget full time in 1985 and 1986. This project focuses on agricultural and socio-economic constraints faced by small farmers (holdings range from 5-50 ha) in Beja Province in a predominantly wheat/barley/livestock farming system.

In the first season (1983/84) of this project, an extensive initial survey of 240 farmers (20% sample) in the project area was conducted. Utilizing information on farm size, machinery ownership, livestock ownership, dominant cropping patterns and existence of off-farm employment this survey allowed the identification of target groups. In 1984/85, 50 representative farmers were selected for detailed follow-up surveys, and 34 of these fifty agreed to have simple on-farm trials on their land. These trials have been used to assess the potential for improved fertilizer and herbicide use in wheat production, and also to assess the potential and constraints facing the introduction of the medic ley system.

5. Training and Agro-Technolgy Transfer (TAT)

An expansion in these activities is planned over the next two years. In 1985, a full time training officer was appointed to assist in the expanded effort in training, and an agronomist in FSP will play an important role in establishing collaborative research programs with national scientists. Training activities in the FSP fall into three major areas, namely: training workshops focusing on particular farming systems research issues; short to medium term training courses for groups of trainees from countries in which FSR is being conducted; and long term training for post graduate students from the region. In addition to these major areas, FSP scientists continue to visit countries in the region in which FSP projects are either underway or are planned, to assist national scientists in the design, execution, and interpretation of their work.

To illustrate the broad scope of our TAT project, some examples from the last two years are given below:

a) Workshop Titles

i) Fertilizer use in dry barley producing areas.

ii) Economic analysis of food legumes on farm trials.

iii) Livestock/forage husbandry farming systems

iv) Crop rotation trials - design and analysis

v) Research methodology for livestock on farm trials

A Regional FSR workshop is held every year. In all, these workshops were attended by 112 regional scientists from 10 different countries.

b) Postgraduate Researchers

We attach special importance to attracting graduate and postgraduate researchers to work with us on topics of importance and relevance to our major goals and objectives. Until now, FSP had 24 such researchers; 8 have received advanced degrees based on their research at ICARDA, 9 are currently involved in degree related research. 1/

c) Residential Training Course

In addition to a variety of short courses which we offer more or less on a demand basis (we gave six such courses in 1984 ranging from FSR methodology to the use of gas chromatography in microbiology), we have developed a six week residential training course for trainees at the research technician level. The first three weeks of the course focuses on general principles of all stages of FSR and the last three weeks offers special courses of the trainees choice in one of the following: agronomy, soil fertility, soil moisture, supplementary irrigation, economics or livestock on farm trial methodology.

IV. INTERNATIONAL COOPERATION

In addition to our considerable training program, FSP collaborative research with national programs is also increasing. Our collaboration in Tunisia is now well established and we have also initiated collaborative research with the Soils Directorate of the Ministry of Agriculture and Agrarian Reform in Syria to investigate improved crop productivity in barley/livestock farming systems in northern Syria. An additional FSR project based in the northwest coastal area of Egypt is currently being considered for funding, and a strong involvement in High Altitude Farming Systems in Pakistan has commenced with the USAID funded project at the Arid Zone Research Institute in Quetta, Baluchistan this year.

In addition to these major associations with FSR projects in Syria, Tunisia, Egypt and Pakistan, we have also developed smaller component specific research projects with several countries. For example:

a) BNF studies on food legumes and forages, Ministry of Agriculture, Cyprus

b) Barley production surveys, University of Cukurova, Turkey

c) Long term climatic data analyses, Aridoculture Center, Morocco

d) Wheat growth simulation models, Aridoculture Center, Morocco

e) FSR methodology assessment workshop, BARD, Pakistan

f) Regional wheat production on vertisols: trials in Syria, Jordan, Cyprus, Tunisia, and Morocco.

g) Soil test calibration for N and P; Syria, Tunisia, Jordan, Morocco, Turkey (in planning stage).

V. A CASE STUDY: FERTILIZER USE ON BARLEY

FSP, in its initial years of research activity, gave priority to barley, a mandate crop of ICARDA and an integral part of the farming systems of the drier regions of WANA. In these regions barley is principally a feed crop and invariably it is the principal feed crop. Barley, livestock (mainly fat-tail sheep and goats) and the steppe and fallow or other non-arable grazing areas form a triangle which constitutes the dominant farming systems of these dry areas. In those areas, this integrated barley-sheep system is the most advantageous alternative in production as barley has relatively higher drought adaptation. Producers in these areas rank barley and/or livestock first as their most important activity (Somel et al.).

Livestock production is important both for meeting growing urban demand but also because dairy products (milk, cheese and yogurt) constitute an important part of the rural diets and are a principal source of calories and high quality protein for the rural populations (Mokbel).

The initial hypothesis developed was that in barley production, the principal limiting factor would be moisture. The producers consider rainfall, a comprehensive concept describing the amount and intra- and inter-seasonal variability of moisture, to be the principal factor limiting yields. 2/

Hence, research was initiated on how the efficiency of use of this scarce factor, moisture, could be increased. The objective of these activities is to seek ways to increase the productivity of land in areas of continuous cropping and to assess the feasibility of increasing croping intensity in areas where fallow is practiced. Clearly, this will involve research on livestock, food and forage legumes (to break monoculture and to replace fallow) as well barley. While we have a multitude of activities in these venues, we will concentrate on a discussion of our barley research.

Survey work in northern Syria, conducted in the 1981/82 cropping season produced the following principal findings:

a) The producers follow either a continuous barley (40%) or a barley-fallow (37%) or a barley-barley-fallow (19%) rotation.

b) Barley production is almost a "mining" activity. Fertilizer use is extremely low; among the sampled farmers 22% use P_2O_5 and 21% use N and they are confined mainly to a particular higher rainfall area. In most cases barley is simply planted and harvested with minimal land preparation.

c) Available soil nutrients indicate severe deficiencies, primarily in phosphorus.

d) Yields are declining and farmers' long run yield expectations vary between 550 kg/ha to 1000 kg/ha according to rainfall zones.

e) Farmers use land races (Arabic white or black) - (and these are being exploited in our barley breeding program.)

In the early years of field trials, diagnostic agronomy work was conducted at two typical barley growing locations in NW Syria, namely Breda (long term seasonal rainfall 278 mm) and Khanasser (215 mm). These trials investigated potentially important management factors including time of sowing, method of sowing, seeding rate, genotype, nitrogen fertilizer and phosphate fertilizer. Whereas many of these factors showed only small and seasonally variable improvements in barley productivity, fertilizer (principally phosphate application) gave consistent and substantial increases in both grain and straw yield (Cooper et al., 1980).

The researchers focused on those results, in particular to the fact that over 85% of the fields in the Barley Survey showed either moderate or severe phosphate deficiency (Somel et al., 1984). In a region where rainfall is low and erratic, both in seasonal and annual distribution, it was clear that any introduction of improved management (such as fertilizer use) must be evaluated with respect to its impact on the water requirements of the crop involved.

In view of the potential yield improvements demonstrated in this early work at Breda and Khanasser, and because widespread nutrient deficiencies were apparent throughout the area, an intensive program of research was initiated to investigate the effect of fertilizer use on productivity, water use and water use efficiency of barley production.

Much of this work was conducted at Breda, and highlights of the research results obtained at this location are summarized in the subsequent sections to illustrate important points.

VI. THE EFFECT OF FERTILIZER ON WATER USE AND WATER USE EFFICIENCY

Between the cropping seasons 1980/81 and 1984/85 trials were run to investigate the effect of fertilizer (phosphate plus nitrogen) on the productivity and water use of barley. Barley was grown in a fallow/barley rotation since this is a predominant rotation practiced by barley producers in NW Syria (Somel, 1984c). In these trials barley was drill planted in the presence and absence of fertilizer and soil moisture dynamics were recorded through the use of the neutron probe technology. Crop evapotranspiration between germination and maturity was calculated by the standard water balance equation. Full details of these trials are reported elsewhere (ICARDA, 1980, 1981, 1982, 1983, 1984). A summary of the results obtained are reported in Table 1.

It is clear that even in very dry years such as 1983/84, substantial responses to fertilizer were obtained without a corresponding increase in water use, resulting in large increases in water use efficiency of production of barley grain and straw. The reasons why such large increases in production are possible without apparently affecting the water requirements of the crop are discussed below.

VII. CROP EVAPOTRANSPIRATION AND ITS COMPONENTS

In measuring crop evapotranspiration (E_T) with the neutron probe, we are in fact measuring two componentss of moisture loss from a cropped field namely (a) water uptake and transpiration by the crop itself (T) and (b) direct evaporation of moisture from the soil surface under the crop (E_{SC}). Thus,

$$E_T = T + E_{SC} \text{ (mm)} \qquad (1)$$

The water use efficiency of dry matter production is defined as:

$$\text{WUE} = \frac{\text{Total Dry Matter Production (kg/ha)}}{\text{Crop Evapotranspiration } (E_T) \text{ (mm)}} \qquad \text{or}$$

$$WUE = TDM / E_T \tag{2}$$

Substituting equation (1) into (2)

$$WUE = TDM / (T + E_{SC}) \tag{3}$$

However, TDM can be defined as the product of Transpiration Efficiency (TE), and the amount of water transpired (T), where TE describes the efficiency of dry matter production per mm of moisture transpired and has units of kg/ha/mm. Thus

$$TDM = TE \times T \tag{4}$$

Substituting equation (4) into (3)

$$WUE = TE / (1 + (E_{SC} / T)); \quad kg/ha/mm \tag{5}$$

(Cooper, 1983)

Transpiration Efficiency is a physiologically controlled parameter, and is largely unaffected by crop management or genotypic differences (Fischer, 1981), and thus any effect that crop management may have on water use efficiency will result almost entirely from changes in the ratio of E_{SC}/T. Cooper, Keatinge and Hughes (1983) have developed a technique for splitting field measurements of evapotranspiration (E_T) into its two components of soil evaporation (E_{SC}) and crop transpiration (T), and this technique has been applied to data collected from several experiments in which the necessary parameters were recorded. An example of the results are given in Table 2.

The results show that, whereas fertilizer (and subsequent improved growth) has not increased crop evapotranspiration, it has resulted in a substantial increase in crop transpiration and a corresponding decrease in soil evaporation. It can be seen that this has caused a significant change in the ratio E_{SC}/T and as predicted by equation (5), a corresponding increase in WUE. As suggested by other work, the effect of fertilizer additions on TE of barley is insignificant.

The mechanism by which fertilizer addition (and subsequent improved crop growth) causes this change in the E_{SC}/T ratio depends on the fact that the principal factor determining the evaporation of moisture from the soil under the crop is the amount of solar radiant energy reaching the soil surface. The more vigorous crop growth and greater leaf area produced by barley receiving fertilizer intercepts a greater percentage of the solar radiant energy and causes increased shading of the soil under the crop. Whereas crop transpiration (T) is thus increased, soil evaporation (E_{SC}) is decreased but crop evapotranspiration (E_T) remains largely unchanged.

In the example illustrated in Table 2, productivity of barley was high, even in the "No Fertilizer" treatment (1720 kg/ha grain yield). Yields in farmers' fields are usually much lower with many farmers reporting expected long term average yields of under 1000 kg/ha in N Syria (Somel, 1984a).

In such cases, it has been estimated (Cooper, 1984) that as little as between 15-25% of the available moisture is being actively used by the crop as transpiration, with the remaining 75-85% being lost as direct evaporation from the soil surface. Such figures indicate very low water use efficiency under current management practices and illustrate the great potential for improved water use efficiency and productivity through the correct use of fertilizer.

VIII. THE EFFECT OF CROP ROTATION ON RESPONSES TO NITROGEN AND PHOSPHATE FERTILIZER

As already stated, the soil moisture research reported in previous sections was conducted on barley grown in a fallow-barley rotations. Concurrent agronomy trials indicated that in such rotations in these dry areas, phosphate fertilizer was the principal factor responsible for increased yields, with nitrogen fertilizer giving significant responses only at certain locations and in certain years (ICARDA, 1982-1984).

However, although fallow-barley is the dominant rotation practiced by farmers in NW Syria, continuous barley cropping is becoming increasingly common in all barley growing regions of the country. Investigations were initiated to assess to what extent the observed fertilizer responses were modified by crop rotation. A 5x5 N-P factorial design was planted in these two contrasting rotations at Breda in the two seasons 1983/84 and 1984/85, and full analyses was performed on all components of yield. The results of total dry matter (grain plus straw) are presented in Table 3 to illustrate the principal main effects of fertilizer application.

Interestingly, these data were collected in a very dry year (1983/84) and a year of average, but well distributed rainfall (1984/85). In general terms, productivity in 1984/85 was more than double that achieved in 1983/84, and barley grown after fallow outyielded barley grown after barley at a given level of fertilizer application in both years. Nevertheless, important differences in fertilizer responses are observed in the two rotations. In both years, highly significant responses were obtained with phosphate fertilizer additions in both rotations, but in contrast, responses to nitrogen fertilizer were observed only in the continuous barley rotation in the dry year, and only limited responses in the presence of phosphate (NxP interaction) were found in the fallow-barley rotation in the wetter year compared to the very large response observed in the barley-barley rotation. Pooled regression analyses of the combined data (not reported here) indicated a highly significant ($p<0.01$) rotation x nitrogen fertilizer interaction in both years.

This observation is supported by studies of mineral nitrogen dynamics ($NO_3 + NH_4$) under fallow (Cooper <u>et al.</u>, 1981) which have clearly shown that during a fallow year, crop available nitrogen accumulates in the soil profile through mineralization of organic matter. Other studies (ICARDA, 1984) show that resulting from this, far greater available nitrogen levels are present in the soil at the onset of the season in a fallow-barley rotation than in continuous barley.

The implications of these results are clear. In assessing the economically optimum fertilizer recommendations for farmers growing barley, the crop rotation practiced by the farmer will need to be considered.

IX. ENVIRONMENTAL VARIABILITY AND MULTIPLE SEASON-MULTIPLE LOCATION TRIALS

One of the salient features of the dry regions is substantial temporal and spatial environmental variability. This is observed in the amount and intra- and inter-seasonal variability as well as spatial variability of rainfall, and spatial variability of soils -- in particular available nutrients.

In such environments, it would be folly to reach conclusions from research until experiments are conducted under as many manifestations of environmental conditions as possible. As such, it is clear that "...the progress of 'knowledge' in more variable environments must be relatively slow, and, presumably, more expensive." (Anderson)

However, the problems of the dry areas have already been neglected and the pressure of needed solutions imply that we do not have the luxury of long time perspective research. Similarly, given scarce resources, one cannot expect to allocate large research funds for long periods before coming up with results.

One alternative suggested to overcome this problem was to implement multiple season-multiple location (MSML) trials with a specific perspective of analysis. Observations from each site/season would be interpreted as observations from a given "state of the environment." With close monitoring of critical environmental variables such as rainfall and available nutrients, space would be substituted for time, hence shortening the time necessary to observe many environmental states through time. Such a model would then be able to relate yield variables both to experimental factors and to environmental factors.

$$Y_{it} = f\ (X_{it}, E_{it})$$

where Y = a yield variable, e.g., TDM as kg/ha

X = vector of experimental factors, e.g., nitrogen fertilizer, kg/ha

E = vector of environment factors, e.g., rainfall, mm

i = site subscript

t = time subscript

The focus would be on pooled analyses of data from the MSML experiments rather than on site-specific analysis. Such pooled analyses would incorporate environmental factors into analysis. Such pooled analysis, i.e., pooling of cross-section and time series is a standard procedure in econometrics. It increases the value of information and allows for statistically more efficient results. Similar approaches have been utilized in agricultural research by Ryan and Perrin (1973, 1974), Colwell, Colwell and Morton, Voss et al., Laird and Cady, Smith and Umali and in the case of Syria by El-Hajj and Matar.

Somel (1984a) used a subset of the data accumulated from trials at five sites and over four seasons (1979-1983) to experiment with this approach. These trials had not originally been designed for a pooled analysis and had been thoroughly analysed on a site-season specific basis (Somel, 1984b).

The results were quite satisfactory. The pooled model incorporated the direct and interaction effects of seasonal rainfall, available phosphorus (P-Olsen), available nitrogen (NO_3) and the experimental variables of seed rate, applied phosphate and nitrogen fertilizer. The model had high and significant explanatory power with adjusted R^2 higher than 0.7 for grain yields. The several possible uses of this general response surface were also demonstrated:

a) The effects of the environmental and experimental variables could be assessed by analysing the partial derivatives of the response surface.

b) Response surfaces could be predicted for given environments such as typical barley growing areas.

c) Optimal input recommendations for such environments could be determined according to average conditions. Furthermore, using probabilities of occurrence of environmental states, the long run results of these recommendations would be assessed. It was indicated that fertilizer recommendations would be expected to pay off around 80% of the time in typical barley growing areas such as Breda.

d) In a counterfactual manner, the value of collecting environmental information and incorporating it into analyses was determined. Again, for typical barley areas like Breda, rainfall information utilized thus would increase net revenues to the farmer by an equivalent of 141 kg/ha of barley while information on soils would increase net return by 93 kg/ha of barley. The implicit production increases would be 425 kg/ha and 318 kg/ha of barley respectively.

e) The effect of increasing the marginal rate of return (MRR) on optimal input levels and long term probabilistic analyses could be assessed. It was found out that MRR higher than 150% would be required to make fertilizer use unattractive.

While these results were treated with caution, there were adequate indications to cause optimism in focusing on fertilizer use on barley. Several concurrent scientist and farmer-managed on-farm trials confirmed these results and gave us confidence about the maturity of our research. We were ready to discuss these results in wider fora. The interest generated provided the momentum for collaborative research activities.

X. COLLABORATIVE RESEARCH

In March 1984 the Soils Directorate of the Syrian Ministry of Agriculture and Agrarian Reform and FSP/ICARDA organized a workshop reviewing research on fertilizer use in the dry areas in which many scientists from the region and international and national research organizations participated (SD/FSP, 1984).

The Soils Directorate has the mandate for making fertilizer recommendations in Syria. Given the relative vacuum of research on barley, there was substantial interest in a collaborative research project.

Such a project was initiated as on-farm research focusing on nitrogen and phosphate fertilizer at 16 sites in Syria during the 1984/85 season.

Apart from fertilizer application and weed control, local practices were followed in land preparation with locally available implements. An effort is being made to build upon the existing base of farmer practices and to produce results appropriate to farmer conditions. Concurrent farmer surveys were carried out to assess farmer reactions.

The project is designed to be analysed as MSML trials. Weekly rainfall is monitored at each site. Available phosphorus and nitrogen are also monitored at each site. The results of the first season are promising (SD/FSP, 1985). Even with one year's results, pooled analysis incorporating soil nutrients, rainfall (disaggregated into the amounts occurring at three stages of growth: plant establishment, plant growth and seed filling) and applied N and P_2O_5 have high explanatory values of adjusted R^2s around 0.90. There are significant responses to fertilizer application particularly with the deficient levels of available nutrients in the soil.

These results of the collaborative research after a single year of trials should be viewed with caution and as tentative. Several years of results are necessary. However, the cooperating Syrian scientists appear to have confidence in the results because they have instructed some of the State Farms in the dry areas to apply fertilizer on barley in an experimental manner. Furthermore, comparison of a baseline survey of participating farmers and farmers from proximate areas indicate that within a year of observing the trials, the proportion using fertilizer have increased from 10% to 35%. 70% indicated use or desire to use fertilizer.

In Syria, fertilizer use on barley, particularly in the dry areas, is discouraged as a matter of policy. Some of these areas are not allocated fertilizer and in other areas credit is not extended for fertilizer purchases. Therefore, the results would indicate a stir in the direction of policy changes.

Subsequent increases in fertilizer use on barley would have beneficial effects in increased and more stable barley production as well as reduced dependence on imports for feedstuffs.

XI. CONCLUSIONS AND FUTURE DIRECTIONS

In this paper we presented the structure and research processes implemented in the FSP at ICARDA. ICARDA is the youngest production center in the CGIAR system. Within its nine years of existence it has tried to meet the challenge of developing research results to meet the urgency of the agricultural problems faced in the region. Utilizing an interdisciplinary FSR perspective has facilitated the comprehension of issues of the complex farming systems of WANA. The FSR perspective has allowed us to identify and focus on critical elements in these systems that casn precipitate change. FSP is gradually moving into collaborative research projects with national scientists to produce concrete results.

These activities are being backed by ICARDA's efforts in producing improved cultivars, agro-ecological zoning and targeting as well as policy research. In particular, as a move to counter the criticism of location specificity and hence the costliness of FSR, we are looking very carefully into the venue of agro-ecological zoning and simulation models to produce generalizable and targeted research results. Depending on the results within the near future, the "international" FSR perspective may start shifting to these areas.

We tried to provide an example with our research on barley, an ICARDA mandate crop. In this particular area, the FSR perspective has allowed us to produce viable results in a short time. We are using and anticipate continuing using the FSR approach profitably in many areas of reseach in WANA.

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Notes

1) Some topics of these research activities are:

- Wheat growth model
- Barley phenology, growth and water use
- Crop rotations for dryland areas
- Barley root production
- Rainfall intensity/erosion
- Human nutrition
- N-dynamics of urea
- Supply response of barley in Syria
- An economic assessment of the Rahad Scheme in the Sudan
- Moisture dynamics in wheat/forage rotations
- Forage barley agronomy
- Fertilizer/herbicide on-farm trials on wheat
- Forage agronomy
- Drought tolerence of lentils
- Women's contribution to agricultural labour

2) In a rare exhibition of consensus in a random sample, all 168 producers in a survey in northern Syria ranked rainfall as the most important factor limiting barley yields, followed by management practices and soils (Somel *et al.*, 1984).

TABLE 1 THE EFFECT OF FERTILIZER ADDITIONS ON PRODUCTIVITY, EVAPOTRANSPIRATION (E_T) AND WATER USE EFFICIENCY (WUE) OF BARLEY AT BREDA, NW SYRIA

Year (Rainfall mm)	Fertilizer	Grain Yield kg/ha	Total Dry Matter kg/ha	E_T (mm) Germ-Mat	WUE of Total Dry Matter kg/ha/mm	% Increase in WUE Due To Fertilizer
1980/81	+ Fert	2580	7540	225	33.5	104
(299)	0 Fert	1620	3840	234	16.4	
1981/82	+ Fert	2220	6130	231	26.5	35
(324)	0 Fert	1320	4540	231	19.7	
1982/83	+ Fert	1490	3400	235	14.5	61
(284)	0 Fert	900	2010	224	9.0	
1983/84	+ Fert	1540	2880	176	16.4	109
(204)	0 Fert	740	1340	171	7.8	
1984/85	+ Fert	2380	4760	242	19.7	228
(278)	0 Fert	750	1420	238	6.0	

TABLE 2 YIELD AND COMPONENTS OF WATER USE BY BARLEY GROWN AT BREDA (1980/81)

	No Fertilizer	Plus Fertilizer 60 P_2O_5, 20 N (kg/ha)
Total Dry Matter (kg/ha)	3550	4940
Grain yield (kg/ha)	1720	2130
E_T (mm)	220	216
E_{SC} (mm)	137	108
T (mm)	83	108
E_{SC} / T	1.65	1.00
WUE (kg/ha/mm)	16.1	22.9
TE (kg/ha/mm)	42.8	45.7

TABLE 3 MAIN EFFECT RESPONSES OF BARLEY TOTAL DRY MATTER PRODUCTION (KG/HA) TO N AND P FERTILIZER IN CONTRASTING ROTATIONS AT BREDA

(F/B = Fallow-Barley, B/B = Barley-Barley)

1983/84	Main Effect N		0	30	60	90	120	kg/ha
(Rainfall, 204 mm)		F/B	2170	2310	2310	2380	2470	
		B/B	1010	1730	1800	1850	1850	
	Main Effect P_2O_5		0	60	120	180	240	kg/ha
		F/B	1420	2020	2470	2730	3000	
		B/B	1270	1590	1680	1910	1780	

F/B $$TDM = 1353 + \underset{**}{10.0}P + \underset{ns}{1.4}N + \underset{ns}{0.009}NP - \underset{ns}{0.002}N^2 - \underset{**}{0.02}P^2 \qquad R^2=0.85$$

B/B $$TDM = 754 + \underset{**}{5.5}P + \underset{**}{19.0}N + \underset{ns}{0.008}NP - \underset{**}{0.115}N^2 - \underset{**}{0.015}P^2 \qquad R^2=0.61$$

1984/85	Main Effect N		0	30	60	90	120	kg/ha
(Rainfall, 278 mm)		F/B	4825	5806	5546	5630	5759	
		B/B	3281	5043	5653	5862	5878	
	Main Effect P_2O_5		0	60	120	180	240	kg/ha
		F/B	3258	5506	5962	6393	6447	
		B/B	2871	5499	5584	5676	6088	

F/B $$TDM = 3320 + \underset{**}{29.6}P + \underset{ns}{11.5}N + \underset{*}{0.06}NP - \underset{ns}{0.11}N^2 - \underset{**}{0.09}P^2 \qquad R^2=0.81$$

B/B $$TDM = 1615 + \underset{**}{30.5}P + \underset{**}{54.0}N + \underset{ns}{0.03}NP - \underset{**}{0.31}N^2 - \underset{**}{0.09}P^2 \qquad R^2=0.79$$

** = $p < 0.01$ * = $p < 0.05$